The Growth-Rings on Herring Scales.

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This note summarises the results of certain investigations on this subject carried out in the Laboratory of the Board of Agriculture and Fisheries. The researches of each author were carried out independently, and their full reports will be published in the Fisheries Investigation Series of Reports of the Board.

The number of scales on Teleostean fish being roughly the same throughout life, it is reasonable to suppose that they follow in their individual growth the growth of the fish as a whole: that when the fish is growing fast the scales grow at a corresponding rate. This differential growth-rate is clearly shown on those scales which are marked with concentric striations, for in these cases the striæ appear closer together when growth is slack than they do when growth is vigorous.

By means of marking experiments, such as have been conducted with salmon, whereby the age of the fish is definitely noted, the alternate close and open growth exhibited by the striæ on the scales have been shown in general to correspond, with some reservations, with the recurring seasons of the year. Hence, in this species, it is possible from observations of the scales to determine, in many instances with a high degree of certainty, the age of the fish. The same method has been applied to other fish, notably the eel, cod, haddock, carp and herring, with varying success. The last-mentioned species has, in recent years, received particular attention; a great mass of data has been collected and conclusions of far-reaching importance deduced.

Between the scales of the salmon and those of the herring, however, a very marked difference exists. Whereas, in the former, the striæ are concentric and thus are capable of reflecting by their grouping the rate of enlargement of the scale as a whole, in the herring, on the other hand, as hitherto described, the striæ are eccentric, and in many cases run in almost straight lines from side to side across the anterior half of the scale. For this reason no differential grouping of striæ can be seen. Instead, at intervals upon the field of the scale, there occur abrupt transparent concentric rings which appear to have no relation whatever with the eccentric striæ. It is, nevertheless, these rings which are regarded as marking recurring periods

of minimum growth corresponding with the winter-season of the year and thus affording an index of the age of the fish.

At present the chief morphological evidence on the point rests upon the observation that, in the majority of cases, scales taken from herring in winter time have what is called a "clear edge"; while those taken from fish in summer appear striated right up to the extreme edge. It is thought, therefore, that the "clear edge" of winter persists in more or less degree and may be identified subsequently as the transparent ring. Not only, however, do many exceptions occur, but it is admitted, by those who have the most thorough acquaintance with scale-reading, that it is not possible to say by inspection whether a transparent ring is in process of formation or no.

It is the purpose of this communication to detail as shortly as possible such additional evidence as we have been able to obtain with respect to the structure and significance of these rings.

Our observations fall under three heads:—

(1) Comparison of dorsal and lateral scales taken from the same fish.

(2) Comparison of the effect produced when the scale is viewed under polarised light with that obtained under ordinary conditions.

(3) The ring as seen in section.

Contrary to common belief, not all the scales of a herring are of the kind described above. If scales be taken from the back, from the region lying between the dorsal fin and the root of the tail, they will be seen to be marked by concentric striæ quite similar in their disposition to those of, say, the salmon. For this reason, such scales indicate clearly a differential growth-rate; further, it can be shown beyond doubt that the limits of the close zones of slow growth coincide in point of position with the transparent rings of lateral scales taken from the same fish. It is fair, therefore, to assume that the transparent ring on the lateral scale does in fact represent a period of minimum growth.

Before discussing our second observation, it should be remarked that the scale of such a fish as the herring is made up of two distinct layers, an upper layer lying unconformably upon a lower, which is itself built up of successive lamellæ added to the inner surface of the scale.

Each lamella, as it is formed, is greater in area than any of those preceding it; and this process coupled with the simultaneous growth in extent of the upper layer brings about the general enlargement of the scale. In section, the upper layer may very clearly be seen lying, unconformably as it were, upon a succession of "outcrops" of the lower. When viewed from above under

polarised light (in conjunction with certain stains) it is this lower lamellar layer (not, as in the previous case, the upper striated layer) which focusses our attention. Under these conditions the scale appears to be made up of a number of concentric bands alternately dark and light.

These bands represent the outcrops of successive lamellæ and are not of equal width but show distinct zoning. Further, if suitable comparisons be made, the limit of the narrow zone will be found to correspond with the transparent ring, just as did the narrow zone of the concentric striæ on the dorsal scales; whilst, in section, the lamellæ which come to the surface at this point not only show very narrow outcrops (as we should expect from our surface view), but show diminished bulk as well. It is clear, therefore, that at the time of the formation of the ridge of the upper layer, the lamellar development of the lower layer was at a minimum.

The physical explanation of the light and dark bands seen under polarised light is to be found in the minute structure of the lamellar layer. The fibres which compose this layer are arranged in two distinct series, one radial, the other concentric; each series is proper to a single lamella, and the lamellæ themselves are arranged in such a manner that the fibres of contiguous lamellæ are at right angles.

As a result of numerous experiments with stained and unstained scales under varying conditions of light, it seemed most probable that the light and dark bands owed their appearance to reflection from the corrugated surfaces of successive outcrops, the corrugations being produced by the individual fibres. That this is the true explanation of the phenomenon is supported by the fact that an effect precisely similar to that of a scale under polarised light may be obtained by engraving upon a piece of copper plate a series of radial and concentric lines in such a manner as to simulate in their arrangement the fibres on the upper surface of the lower layer of a herring scale as ascertained by dissection.

Apart, however, from the physical explanation of the polarisation effect it is obvious that the method affords a most valuable check on the reading of scales by ordinary light and affords important corroborative evidence, when taken in conjunction with that adduced already, of the truth of the view that the transparent rings do indeed mark recurring periods of minimum growth.